U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 USC 371 AND 37 CFR 1.491

ATTORNEY DOCKET NO.	
401530	
U.S. APPLICATION NO.	
10/030986	
INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE
PCT/JP00/03994	June 19, 2000
PRIORITY DATE CLAIMED	

TITLE OF INVENTION
EXCITATION CONTROL DEVICE AND EXCITATION CONTROL METHOD

APPLICANT(S) FOR DO/EO/US
KITAMURA ET AL.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 USC 371 and 37 CFR 1.491.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 USC 371 and 37 CFR 1.491.
3. ☒ This is an express request to begin national examination procedures (35 USC 371(f)).
4. ☒ The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).
5. ☒ A copy of the International Application as filed (35 USC 371(c)(2))
   a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   b. ☒ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 USC 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 USC 371(c)(3))
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 USC 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 USC 371(c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 USC 371(c)(5)).
11. Nucleotide and/or Amino Acid Sequence Submission
    a. ☐ Computer Readable Form (CRF)
    b. Specification Sequence Listing on:
       i. ☐ CD-ROM or CD-R (2 copies); or
       ii. ☐ Paper Copy
    c. ☐ Statement verifying identity of above copies

Items 12 to 19 below concern other document(s) or information included:

12. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
    ☒ Form PTO-1449
    ☒ Copies of Listed Documents
13. ☒ An assignment for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
14. ☒ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☒ Application Data Sheet Under 37 CFR 1.76
18. ☒ Return Receipt Postcard
19. ☒ Other items or information: Drawings (7 sheets)

U.S. APPLICATION NO.	INTERNATIONAL APPLICATION NO.	ATTORNEY DOCKET NO.
10/030986	PCT/JP00/03994	401530

20. ☒ The following fees are submitted:	CALCULATIONS	PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5)):		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO $1,040.00		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO $890.00		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO, but international search fee (37 CFR 1.445(a)(2)) paid to USPTO $740.00		
International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) $710.00		
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1) to (4) $100.00		
ENTER APPROPRIATE BASIC FEE AMOUNT=	$890.00	
Surcharge of $130.00 for furnishing the National fee or oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date	$	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total Claims	4 -20=		x $ 18.00	$	
Independent Claims	2 - 3 =		x $ 84.00	$	
☐ Multiple Dependent Claim(s) (if applicable)			+$280.00	$	

TOTAL OF ABOVE CALCULATIONS=	$890.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.	$	
SUBTOTAL=	$890.00	
Processing fee of **$130.00** for furnishing English Translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date.	$	
TOTAL NATIONAL FEE=	$890.00	
Fee for recording the enclosed assignment. The assignment must be accompanied by an appropriate cover sheet. **$40.00** per property +	$40.00	
TOTAL FEE ENCLOSED=	$930.00	
	Amount to be: refunded	$
	charged:	$

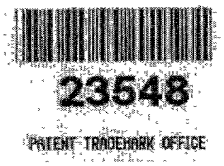
a. ☒ A check in the amount of $930.00 to cover the above fee is enclosed.

b. ☐ Please charge Deposit Account No. 12-1216 in the amount of $ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 12-1216. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:



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Date: January 16, 2002

PATENT
Attorney Docket No. 401530/SHINSEI

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

KITAMURA et al.

Application No. Unassigned

Art Unit: Unassigned

Examiner: Unassigned

Filed: January 16, 2002

For: EXCITATION CONTROL DEVICE AND EXCITATION CONTROL METHOD

PRELIMINARY AMENDMENT

Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

Prior to the examination of the above-identified patent application, please enter the following amendments and consider the following remarks.

IN THE CLAIMS:

Replace the indicated claims with:

1. (Amended) An excitation control device comprising:

voltage detecting means for detecting a voltage of an output terminal of a synchronous machine which is connected to a power transmission system through a transformer;

reactive current detecting means for detecting a reactive current output from the synchronous machine;

voltage setting means for setting a reference voltage of the output terminal of the synchronous machine according to the reactive current detected by the reactive current detecting means, a reference voltage of an output side of the transformer, and a phase compensation transfer function to quicken attenuation of an electric power fluctuation; and

control means for controlling an exciting system of the synchronous machine according to a difference between the reference voltage set by the voltage setting means and the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.

2. (Amended) The excitation control device according to claim 1, wherein the reference voltage of the output terminal of the synchronous machine is set by the voltage setting means based on the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.

3. (Amended) An excitation control method, comprising:

detecting a voltage of an output terminal of a synchronous machine which is connected to a power transmission system through a transformer;

detecting a reactive current output from the synchronous machine;

setting a reference voltage of the output terminal of the synchronous machine according to the reactive current, a reference voltage of an output side of the transformer, and a phase compensation transfer function to quicken attenuation of an electric power fluctuation; and

controlling an exciting system of the synchronous machine according to a difference between the reference voltage of the output terminal of the synchronous machine and the voltage of the output terminal of the synchronous machine.

4 (Amended) The excitation control method according to claim 3, wherein setting the reference voltage of the output terminal of the synchronous machine includes setting the reference voltage of the output terminal of the synchronous machine based on the voltage of the output terminal of the synchronous machine.

IN THE ABSTRACT:

Replace the Abstract with:

ABSTRACT OF THE DISCLOSURE

A reference voltage of an output terminal of a synchronous machine is set according to a reactive current output from the synchronous machine, a reference voltage of the high voltage side of a transformer, and a phase compensation transfer function to quicken attenuation of an electric power fluctuation.

REMARKS

The foregoing Amendment corrects translational errors and conforms the claims to United States practice. No new matter is added.

Respectfully submitted,

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Examiner: Unassigned

AMENDMENTS TO CLAIMS AND ABSTRACT MADE VIA PRELIMINARY AMENDMENT

Amendments to existing claims:

1. (Amended) An excitation control device~~,~~ comprising:

voltage detecting means for detecting a voltage of an output terminal of a synchronous machine which is connected to a power transmission system through a transformer;

reactive current detecting means for detecting a reactive current output from the synchronous machine;

voltage setting means for setting a reference voltage of the output terminal of the synchronous machine according to the reactive current detected by the reactive current detecting means, a reference voltage of an output side of the transformer, and a ~~function of~~ phase compensation ~~used~~ transfer function to quicken ~~the~~ attenuation of an electric power fluctuation; and

control means for controlling an exciting system of the synchronous machine according to a difference between the reference voltage set by the voltage setting means and the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.

2. (Amended) ~~An~~ The excitation control device according to claim 1, wherein the reference voltage of the output terminal of the synchronous machine is set by the voltage setting means ~~by considering~~ based on the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.

3. (Amended) An excitation control method, comprising ~~the steps of~~:

detecting a voltage of an output terminal of a synchronous machine which is connected to a power transmission system through a transformer;

detecting a reactive current output from the synchronous machine;

setting a reference voltage of the output terminal of the synchronous machine according to the reactive current, a reference voltage of an output side of the transformer, and a ~~function of~~ phase compensation ~~used~~ transfer function to quicken ~~the~~ attenuation of an electric power fluctuation; and

controlling an exciting system of the synchronous machine according to a difference between the reference voltage of the output terminal of the synchronous machine and the voltage of the output terminal of the synchronous machine.

4. (Amended) ~~An~~ The excitation control method according to claim 3, wherein ~~the step of~~ setting the reference voltage of the output terminal of the synchronous machine includes ~~the step of~~ setting the reference voltage of the output terminal of the synchronous machine ~~by considering~~ based on the voltage of the output terminal of the synchronous machine.

Amendments to the abstract:

ABSTRACT OF THE DISCLOSURE

A reference voltage ~~V_{Gref}~~ of an output terminal of a synchronous machine ~~21~~ is set according to a reactive current ~~I_Q~~ output from the synchronous machine ~~21~~, a reference voltage ~~V_{Href}~~ of the high voltage side of a transformer ~~22~~, and a ~~transfer function $F_{H1}(s)$ of~~ phase compensation ~~used~~ transfer function to quicken ~~the~~ attenuation of an electric power fluctuation.

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Attorney Docket No. 401530/SHINSEI

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In re Application of:

KITAMURA et al.

Application No. Unassigned

Filed: January 16, 2002

For: EXCITATION CONTROL DEVICE AND EXCITATION CONTROL METHOD

Art Unit: Unassigned

Examiner: Unassigned

PENDING CLAIMS AFTER ENTRY OF PRELIMINARY AMENDMENT

1. An excitation control device comprising:

voltage detecting means for detecting a voltage of an output terminal of a synchronous machine which is connected to a power transmission system through a transformer;

reactive current detecting means for detecting a reactive current output from the synchronous machine;

voltage setting means for setting a reference voltage of the output terminal of the synchronous machine according to the reactive current detected by the reactive current detecting means, a reference voltage of an output side of the transformer, and a phase compensation transfer function to quicken attenuation of an electric power fluctuation; and

control means for controlling an exciting system of the synchronous machine according to a difference between the reference voltage set by the voltage setting means and the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.

2. The excitation control device according to claim 1, wherein the reference voltage of the output terminal of the synchronous machine is set by the voltage setting means based on the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.

3. An excitation control method, comprising:

detecting a voltage of an output terminal of a synchronous machine which is connected to a power transmission system through a transformer;

detecting a reactive current output from the synchronous machine;

setting a reference voltage of the output terminal of the synchronous machine according to the reactive current, a reference voltage of an output side of the transformer, and a phase compensation transfer function to quicken attenuation of an electric power fluctuation; and

controlling an exciting system of the synchronous machine according to a difference between the reference voltage of the output terminal of the synchronous machine and the voltage of the output terminal of the synchronous machine.

4 The excitation control method according to claim 3, wherein setting the reference voltage of the output terminal of the synchronous machine includes setting the reference voltage of the output terminal of the synchronous machine based on the voltage of the output terminal of the synchronous machine.

SPECIFICATION

TITLE OF THE INVENTION

EXCITATION CONTROL DEVICE AND EXCITATION CONTROL METHOD

TECHNICAL FIELD

The present invention relates to an excitation control device and an excitation control method used for both the stabilization of voltage in an electric power system and the improvement of steady-state stability in the electric power system.

BACKGROUND ART

Fig. 1 is constitutional view of a conventional excitation control device. In Fig. 1, 1 indicates a synchronous machine. 2 indicates a transformer. 3 indicates a circuit breaker. 4 indicates a power transmission line. 5 indicates a power transmission bus line. 6 indicates a potential transformer (hereinafter, called PT) for detecting a voltage V_G of an output terminal of the synchronous machine 1. 7 indicates a current transformer (hereinafter, called CT) for detecting a reactive current I_Q output from the synchronous machine 1. 8 indicates a voltage setting device for setting a reference voltage V_{Gref} of the output terminal of the synchronous machine 1 according to both the reactive current I_Q detected in the CT 7 and a reference voltage V_{Href} of the high voltage side of the transformer 2.

9 indicates a subtracting unit for subtracting the output terminal voltage V_G detected in the PT 6 from the reference voltage V_{Gref} set in the voltage setting device 8 to obtain a subtraction value and outputting a difference signal indicating the subtraction value. 10 indicates an automatic voltage regulating device (hereinafter, called AVR) for controlling a commutation timing of an exciter 11 by using

the difference signal output from the subtracting unit 9 as an input condition for a transfer function. 11 indicates the exciter for supplying a field current to a field winding 12 of the synchronous machine 1 according to an instruction of the AVR 10. 12 indicates the field winding of the synchronous machine 1.

Fig. 2 is a flow chart showing a conventional excitation control method.

Next, an operation will be described.

A voltage V_G of the output terminal of the synchronous machine 1 is detected in the PT 6 (step ST1), and a reactive current I_Q output from the synchronous machine 1 is detected in the CT 7 and the PT 6 (step ST2).

When the reactive current I_Q is detected in the CT 7, a reference voltage V_{Gref} of the output terminal of the synchronous machine 1 is set in the voltage setting device 8 according to both the reactive current I_Q and a reference voltage V_{Href} of the high voltage side of the transformer 2 (step ST3).

Hereinafter, a setting method of the reference voltage V_{Gref} is described.

A relation between the voltage V_G of the output terminal of the synchronous machine 1 and a voltage V_H of the high voltage side of the transformer 2 is expressed according to an equation (1).

$$V_G = V_H + X_t \times I_Q \qquad (1)$$

Here, the symbol X_t in the equation (1) denotes a reactance of the transformer 2.

Also, as shown in Fig. 3, in cases where a plurality of synchronous machines 1 are connected to a power transmission system, reactance of each synchronous machine 1 with another synchronous machine 1 is equal to almost zero by applying the equation (1) as a relation between the reference voltage V_{Gref} and the reference voltage V_{Href}, a cross

current flows from one synchronous machine 1 to another synchronous machine 1 due to both a voltage difference of the output terminal voltages V_G and a response difference in each synchronous machine 1 with another synchronous machine 1, and each synchronous machine 1 has an excessive load. To suppress the generation of the cross current, as is expressed according to an equation (2), a reactance X_{DR} corresponding to the suppression of the cross current is subtracted from the reactance X_t of the transformer 2. Here, the reactance X_{DR} corresponding to the suppression of the cross current is set to a value equal to several % of the reactance X_t of the transformer 2, and the value of the reactance X_{DR} is empirically set.

$$V_{Gref} = V_{Href} + (X_t - X_{DR}) \times I_Q \quad (2)$$

Therefore, the reference voltage V_{Gref} of the output terminal of the synchronous machine 1 is calculated in the voltage setting device 8 by substituting the reactive current I_Q output from the synchronous machine 1 and the reference voltage V_{Href} of the high voltage side of the transformer 2 into the equation (2).

When the reference voltage V_{Gref} of the output terminal of the synchronous machine 1 is set in the voltage setting device 8, the voltage V_G of the output terminal of the synchronous machine 1 detected in the PT 6 is subtracted in the subtracting unit 9 from the reference voltage V_{Gref} set in the voltage setting device 8 to obtain a subtraction value, and a difference signal indicating the subtraction value is output (step ST4).

When the difference signal is output from the subtracting unit 9, a timing signal for controlling a commutation timing of the exciter 11 is produced in the AVR 10, for example, by using the difference signal as an input condition for a following transfer function (step ST5).

$$\text{Transfer Function} = K \times (1 + T_{LD} \times s)/(1 + T_{LG} \times s) \quad (3)$$

Here, the symbol K denotes a gain constant, the symbols T_{LD} and T_{LG} denote time constants, and the symbol s denotes a Laplace operator.

When the timing signal output from the AVR 10 is received in the exciter 11, a field current is supplied to the field winding 12 of the synchronous machine 1 according to the timing signal (step ST6). Here, when the difference signal output from the subtracting unit 9 is equal to a positive value, the field current supplied to the field winding 12 is increased, and the voltage V_G of the output terminal of the synchronous machine 1 is heightened. In contrast, when the difference signal output from the subtracting unit 9 is equal to a negative value, the field current supplied to the field winding 12 is decreased, and the voltage V_G of the output terminal of the synchronous machine 1 is lowered.

Therefore, the voltage V_G of the output terminal of the synchronous machine 1 is controlled so as to agree with the reference voltage V_{Gref}. Also, when the reactive current I_Q output from the synchronous machine 1 is equal to zero, the voltage V_H of the high voltage side of the transformer 2 is controlled so as to agree with the reference voltage V_{Href}.

$$V_G = V_{Href} + (X_t - X_{DR}) \times I_Q \quad (4)$$

$$V_H = V_{Href} - X_{DR} \times I_Q \quad (5)$$

Therefore, because the voltage of the power transmission bus line 5 is maintained to a constant value, even though a failure occurs, for example, in the power transmission line 4, the lowering of the voltage in the whole power transmission system can be lessened.

Because the conventional excitation control device has the above-described configuration, even though a failure occurs in the power transmission line 4, the lowering of the voltage in the whole power transmission system can be lessened. However, because no means for quickening the attenuation of an electric power fluctuation of

power transmission system occurring due to a failure of the power transmission system is arranged in the conventional excitation control device, a problem has arisen that it is required to additionally arrange a power system stabilization control device (PSS) for the purpose of quickening the attenuation of an electric power fluctuation.

The present invention is provided to solve the above-described problem, and the object of the present invention is to provide an excitation control device and an excitation control method in which the attenuation of an electric power fluctuation is quickened while controlling a voltage of the high voltage side of a transformer to a constant value.

DISCLOSURE OF THE INVENTION

An excitation control device of the present invention comprises a voltage setting means for setting a reference voltage of an output terminal of a synchronous machine according to a reactive current detected by a reactive current detecting means, a reference voltage of an output side of a transformer and a function of phase compensation used to quicken the attenuation of an electric power fluctuation.

Therefore, a voltage on the output side of the transformer can be set to a constant value, and the attenuation of the electric power fluctuation can be quickened.

In the excitation control device of the present invention, the reference voltage of the output terminal of the synchronous machine is set by the voltage setting means by considering the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.

Therefore, the attenuation of the electric power fluctuation can be adjusted to a desired speed.

An excitation control method of the present invention comprises the step of setting a reference voltage of an output terminal of a synchronous machine according to a reactive current output from the synchronous machine, a reference voltage of an output side of a transformer and a function of phase compensation used to quicken the attenuation of an electric power fluctuation.

Therefore, a voltage on the output side of the transformer can be set to a constant value, and the attenuation of the electric power fluctuation can be quickened.

In the excitation control method of the present invention, the reference voltage of the output terminal of the synchronous machine is set by considering the voltage of the output terminal of the synchronous machine.

Therefore, the attenuation of the electric power fluctuation can be adjusted to a desired speed.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is constitutional view of a conventional excitation control device.

Fig. 2 is a flow chart showing a conventional excitation control method.

Fig. 3 is a system view showing an infinite bus line model.

Fig. 4 is constitutional view of an excitation control device according to a first embodiment of the present invention.

Fig. 5 is a flow chart showing an excitation control method according to the first embodiment of the present invention.

Fig. 6 is an explanatory view showing an internal configuration of a voltage setting device with electric power system stabilization function.

Fig. 7 is constitutional view of an excitation control device

according to a second embodiment of the present invention.

Fig. 8 is a flow chart showing an excitation control method according to the second embodiment of the present invention.

Fig. 9 is an explanatory view showing an internal configuration of a voltage setting device with electric power system stabilization function.

BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter, the best mode for carrying out the present invention will now be described with reference to the accompanying drawings to explain the present invention in more detail.

EMBODIMENT 1

Fig. 4 is constitutional view of an excitation control device according to a first embodiment of the present invention. In Fig. 4, 21 indicates a synchronous machine. 22 indicates a transformer. 23 indicates a circuit breaker. 24 indicates a power transmission line. 25 indicates a power transmission bus line of a power plant. 26 indicates a PT (or a voltage detecting means), denoting a potential transformer, for detecting a voltage V_G of an output terminal of the synchronous machine 21. 27 indicates a CT (or a reactive current detecting means), denoting a current transformer, for detecting a reactive current I_Q output from the synchronous machine 21. 28 indicates a voltage setting device with electric power system stabilization function (or a voltage setting means) for setting a reference voltage V_{Gref} of the output terminal of the synchronous machine 21 according to the reactive current I_Q detected in the CT 27, a reference voltage V_{Href} of the high voltage side of the transformer 22 and a transfer function $F_{H1}(s)$ of phase compensation used to quicken the attenuation of an electric power fluctuation of a power transmission system.

29 indicates a subtracting unit for subtracting the output terminal voltage V_G detected in the PT 26 from the reference voltage V_{Gref} set in the voltage setting device with electric power system stabilization function 28 to produce a subtraction value and outputting a difference signal indicating the subtraction value. 30 indicates an AVR, denoting an automatic voltage regulating device, for controlling a commutation timing of an exciter 31 by using the difference signal output from the subtracting unit 29 as an input condition for a transfer function of commutation timing. 31 indicates the exciter for supplying a field current to a field winding 32 of the synchronous machine 21 according to an instruction of the AVR 30. 32 indicates the field winding of the synchronous machine 21. Here, control means comprises the subtracting unit 29, the AVR 30 and the exciter 31.

Fig. 5 is a flow chart showing an excitation control method according to a first embodiment of the present invention, and Fig. 6 is an explanatory view showing an internal configuration of the voltage setting device with electric power system stabilization function 28.

Next an operation will be described below.

A voltage V_G of the output terminal of the synchronous machine 21 is detected in the PT 26 (step ST11), and a reactive current I_Q output from the synchronous machine 21 is detected in the CT 27 (step ST12).

When the reactive current I_Q is detected in the CT 27, a reference voltage V_{Gref} of the output terminal of the synchronous machine 21 is set in the voltage setting device with electric power system stabilization function 28 according to the reactive current I_Q, a reference voltage V_{Href} of the high voltage side of the transformer 22 and a transfer function $F_{H1}(s)$ of phase compensation used to quicken the attenuation of an electric power fluctuation (step ST13). In detail, the reference voltage V_{Gref} of the output terminal of the synchronous machine 21 is calculated by substituting the reactive current I_Q, the

reference voltage V_{Href} and the transfer function $F_{H1}(s)$ into the equation (6) (refer to Fig. 6).

$$V_{Gref} = V_{Href} + F_{H1}(s) \times (X_t - X_{DR}) \times I_Q \quad (6)$$

Here, the symbol X_t in the equation (6) denotes a reactance of the transformer 22, and the symbol X_{DR} denotes a reactance corresponding to the suppression of a cross current flowing in cases where a plurality of synchronous machines 21 are connected to a power transmission line. Also, $F_{H1}(s)$ denotes a transfer function in a phase compensation circuit in which a signal indicating a timing appropriate to quicken the attenuation of an electric power fluctuation is produced. For example, $F_{H1}(s)$ is set to a transfer function expressed according to an equation (7).

$$F_{H1}(s) = a_{1n} \times s^n + a_{1(n-1)} \times s^{n-1} + \text{---} + a_{11} \times s + a_{10} \quad (7)$$

wherein the symbol s denotes a Laplace operator, and the symbols a denote constant values respectively.

Here, to make a voltage V_H of the high voltage side of the transformer 22 agree with the reference voltage V_{Href} in a normal operation, it is required to set each constant a of the equation (7) so as to set a gain of $F_{H1}(s)$ to 1 in the normal operation.

Thereafter, when the reference voltage V_{Gref} of the output terminal of the synchronous machine 21 is set in the voltage setting device with electric power system stabilization function 28, the voltage V_G of the output terminal of the synchronous machine 21 detected in the PT 26 is subtracted in the subtracting unit 29 from the reference voltage V_{Gref} set in the voltage setting device with electric power system stabilization function 28 to obtain a subtraction value, and a difference signal indicating the subtraction value is output (step ST14).

Thereafter, a timing signal for controlling a commutation timing of the exciter 31 is produced in the AVR 30 when the difference signal

output from the subtracting unit 29 is received as an input signal (step ST15).

Thereafter, when the timing signal output from the AVR 30 is received in the exciter 31, a field current is supplied from the exciter 31 to the field winding 32 of the synchronous machine 21 according to the timing signal (step ST16).

Here, when the difference signal output from the subtracting unit 29 is equal to a positive value, the field current supplied to the field winding 32 is increased, and the voltage V_G of the output terminal of the synchronous machine 21 is heightened. In contrast, when the difference signal output from the subtracting unit 29 is equal to a negative value, the field current supplied to the field winding 32 is decreased, and the voltage V_G of the output terminal of the synchronous machine 21 is lowered.

Therefore, the voltage V_G of the output terminal of the synchronous machine 21 is controlled so as to agree with the reference voltage V_{Gref}.

Also, the voltage V_G of the output terminal of the synchronous machine 21 has relation to the voltage V_H of the high voltage side of the transformer 22 according to an equation (8). Therefore, the voltage V_G of the output terminal of the synchronous machine 21 and the voltage V_H of the high voltage side of the transformer 22 are expressed according to equations (9) and (10) respectively by using the reference voltage V_{Href} of the high voltage side of the transformer 22.

$$V_H = V_G - X_t \times I_Q \quad (8)$$

$$V_G = V_{Href} + (X_t - X_{DR}) \times I_Q \quad (9)$$

$$V_H = V_{Href} - X_{DR} \times I_Q \quad (10)$$

Therefore, when the reactive current I_Q output from the synchronous machine 21 is equal to zero, the voltage V_H of the high voltage side of the transformer 22 can be controlled so as to agree with the

reference voltage V_{Href}.

As is described above, in the first embodiment, the reference voltage V_{Gref} of the output terminal of the synchronous machine 21 is set according to the reactive current I_Q output from the synchronous machine 21, the reference voltage V_{Href} of the high voltage side of the transformer 22 and the transfer function $F_{H1}(s)$ of phase compensation used to quicken the attenuation of an electric power fluctuation. Therefore, the voltage V_H of the high voltage side of the transformer 22 can be controlled to a constant value. As a result, even though a failure occurs in the power transmission system or a load on the power transmission system is rapidly increased, the voltage V_H of the high voltage side of the transformer 22 can be stabilized. Also, because the attenuation of an electric power fluctuation can be quickened, the steady-state stability in an electric power system can be heightened.

EMBODIMENT 2

Fig. 7 is constitutional view of an excitation control device according to a second embodiment of the present invention. The constituent elements, which are the same as those shown in Fig. 4, are indicated by the same reference numerals as those of the constituent elements shown in Fig. 4, and additional description of those constituent elements is omitted.

33 indicates a voltage setting device with electric power system stabilization function (or a voltage setting means) for setting a reference voltage V_{Gref} of the output terminal of the synchronous machine 21 according to a reactive current I_Q detected in the CT 27, an output terminal voltage V_G detected in the PT 26, a reference voltage V_{Href} of the high voltage side of the transformer 22 and a transfer function $F_{H2}(s)$ of phase compensation used to quicken the attenuation

of an electric power fluctuation.

Fig. 8 is a flow chart showing an excitation control method according to the second embodiment of the present invention, Fig. 9 is an explanatory view showing an internal configuration of the voltage setting device with electric power system stabilization function 33.

Next an operation will be described below.

In the first embodiment, the reference voltage V_{Gref} of the output terminal of the synchronous machine 21 is set according to the reactive current I_Q output from the synchronous machine 21, the reference voltage V_{Href} of the high voltage side of the transformer 22 and the transfer function $F_{H1}(s)$ of phase compensation used to quicken the attenuation of an electric power fluctuation. However, it is preferred that a reference voltage V_{Gref} of the output terminal of the synchronous machine 21 is set by considering an output terminal voltage V_G detected in the PT 26.

In detail, as shown in Fig. 9, a reference voltage V_{Gref} of the output terminal of the synchronous machine 21 is set in the voltage setting device with electric power system stabilization function 33 according to a reactive current I_Q detected in the CT 27, an output terminal voltage V_G detected in the PT 26, a reference voltage V_{Href} of the high voltage side of the transformer 22 and a transfer function $F_{H2}(s)$ of phase compensation used to quicken the attenuation of an electric power fluctuation (step ST17).

$$V_{Gref} = V_{Href} + (X_t - X_{DR}) \times I_Q + \{V_{Href} + (X_t - X_{DR}) \times I_Q - V_G\} \times F_{H2}(s) \qquad (11)$$

Here, the symbol X_t in the equation (11) denotes a reactance of the transformer 22, and the symbol X_{DR} denotes a reactance corresponding to the suppression of a cross current flowing in cases where a plurality of synchronous machines 21 are connected to a power transmission line. Also, $F_{H2}(s)$ denotes a transfer function in a phase compensation circuit

in which a signal indicating a timing appropriate to quicken the attenuation of an electric power fluctuation is produced. For example, $F_{H2}(s)$ is set to a transfer function expressed according to an equation (12).

$$F_{H2}(s) = a_{2n} \times s^{n} + a_{2(n-1)} \times s^{n-1} + \text{---} + a_{21} \times s + a_{20} \quad (12)$$

wherein the symbol s denotes a Laplace operator, and the symbols a denote constant values respectively.

As is described above, in cases where the reference voltage V_{Gref} of the output terminal of the synchronous machine 21 is calculated, even though the transfer function $F_{H2}(s)$ is set to any value, the voltage V_H of the high voltage side of the transformer 22 agrees with the reference voltage V_{Href} in a normal operation (because $V_{Href} + (X_t - X_{DR}) \times I_Q - V_G = 0$ is satisfied in the normal operation). Therefore, the excitation control device of the second embodiment differs from that of the first embodiment in that it is not required to set a gain of $F_{H2}(s)$ to 1 in the normal operation, and the attenuation of an electric power fluctuation can be adjusted to a desired speed.

INDUSTRIAL APPLICABILITY

As is described above, in cases where an exciting system of a synchronous machine is controlled, the excitation control device and the excitation control method according to the present invention is appropriate to perform the stabilization of voltage in an electric power system and the improvement of steady-state stability in the electric power system.

WHAT IS CLAIMED IS:

1. An excitation control device, comprising:

voltage detecting means for detecting a voltage of an output terminal of a synchronous machine which is connected to a power transmission system through a transformer;

reactive current detecting means for detecting a reactive current output from the synchronous machine;

voltage setting means for setting a reference voltage of the output terminal of the synchronous machine according to the reactive current detected by the reactive current detecting means, a reference voltage of an output side of the transformer and a function of phase compensation used to quicken the attenuation of an electric power fluctuation; and

control means for controlling an exciting system of the synchronous machine according to a difference between the reference voltage set by the voltage setting means and the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.

2. An excitation control device according to claim 1, wherein the reference voltage of the output terminal of the synchronous machine is set by the voltage setting means by considering the voltage of the output terminal of the synchronous machine detected by the voltage detecting means.

3. An excitation control method, comprising the steps of:

detecting a voltage of an output terminal of a synchronous machine which is connected to a power transmission system through a transformer;

detecting a reactive current output from the synchronous machine;

setting a reference voltage of the output terminal of the synchronous

machine according to the reactive current, a reference voltage of an output side of the transformer and a function of phase compensation used to quicken the attenuation of an electric power fluctuation; and

controlling an exciting system of the synchronous machine according to a difference between the reference voltage of the output terminal of the synchronous machine and the voltage of the output terminal of the synchronous machine.

4. An excitation control method according to claim 3, wherein the step of setting the reference voltage of the output terminal of the synchronous machine includes the step of

setting the reference voltage of the output terminal of the synchronous machine by considering the voltage of the output terminal of the synchronous machine.

FIG.1

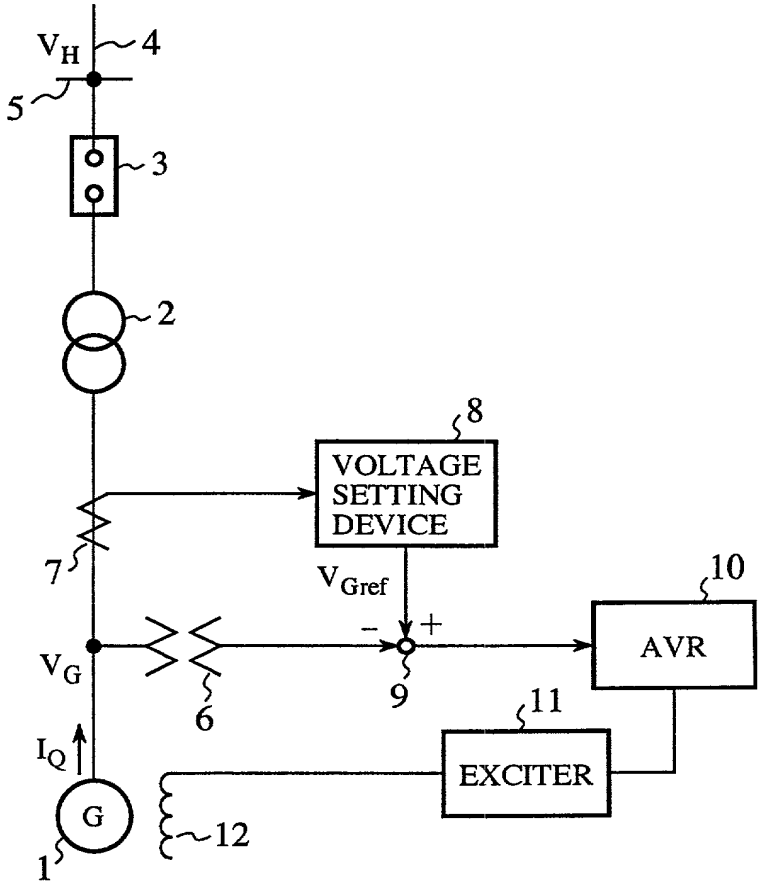

V_H
4
5
3
2
8
VOLTAGE SETTING DEVICE
7
V_{Gref}
10
AVR
V_G
6
9
11
I_Q
EXCITER
G
12
1

FIG.2

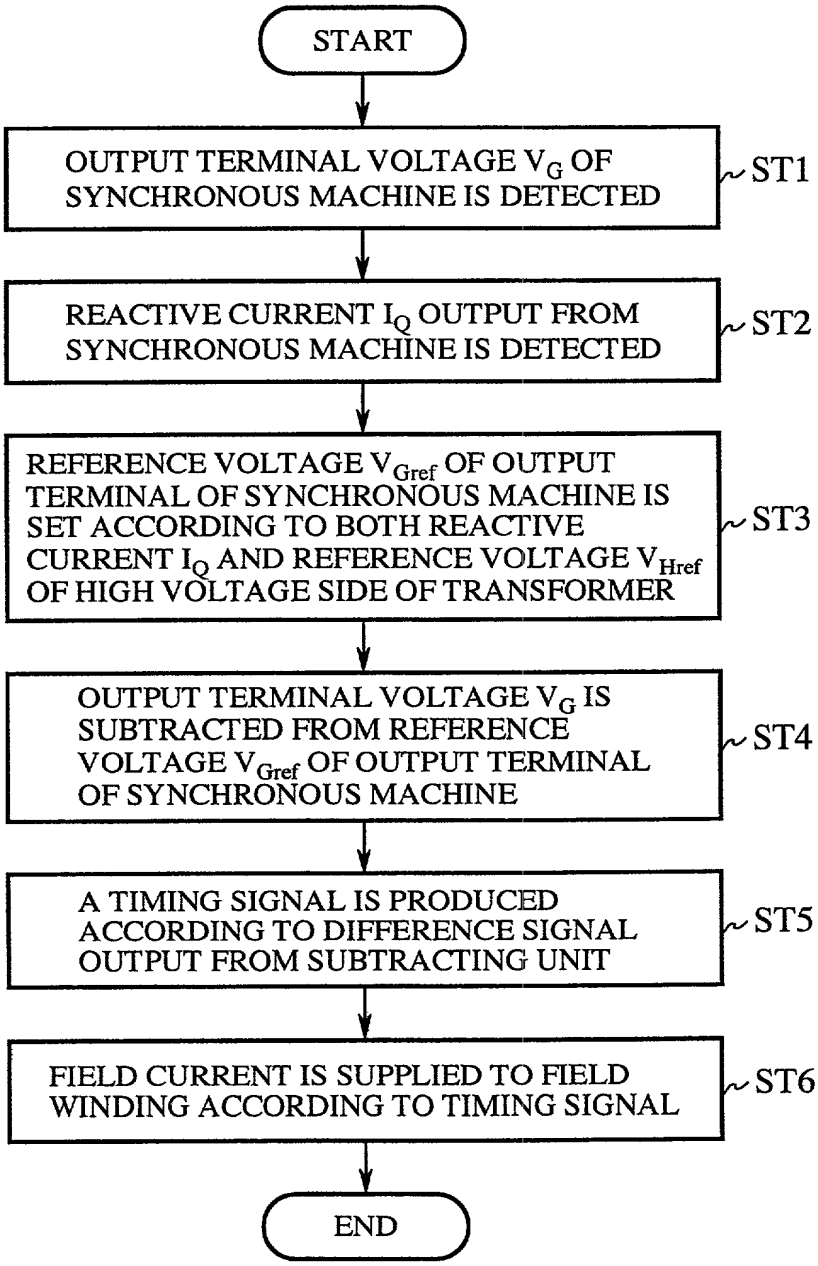

START
OUTPUT TERMINAL VOLTAGE V_G OF SYNCHRONOUS MACHINE IS DETECTED
ST1
REACTIVE CURRENT I_Q OUTPUT FROM SYNCHRONOUS MACHINE IS DETECTED
ST2
REFERENCE VOLTAGE V_{Gref} OF OUTPUT TERMINAL OF SYNCHRONOUS MACHINE IS SET ACCORDING TO BOTH REACTIVE CURRENT I_Q AND REFERENCE VOLTAGE V_{Href} OF HIGH VOLTAGE SIDE OF TRANSFORMER
ST3
OUTPUT TERMINAL VOLTAGE V_G IS SUBTRACTED FROM REFERENCE VOLTAGE V_{Gref} OF OUTPUT TERMINAL OF SYNCHRONOUS MACHINE
ST4
A TIMING SIGNAL IS PRODUCED ACCORDING TO DIFFERENCE SIGNAL OUTPUT FROM SUBTRACTING UNIT
ST5
FIELD CURRENT IS SUPPLIED TO FIELD WINDING ACCORDING TO TIMING SIGNAL
ST6
END

FIG.3

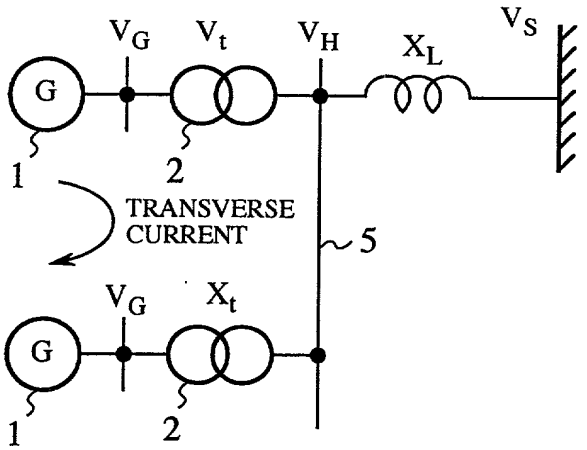

V_G
V_t
V_H
X_L
V_S
G
1
2
TRANSVERSE CURRENT
5
V_G
X_t
G
1
2

FIG.4

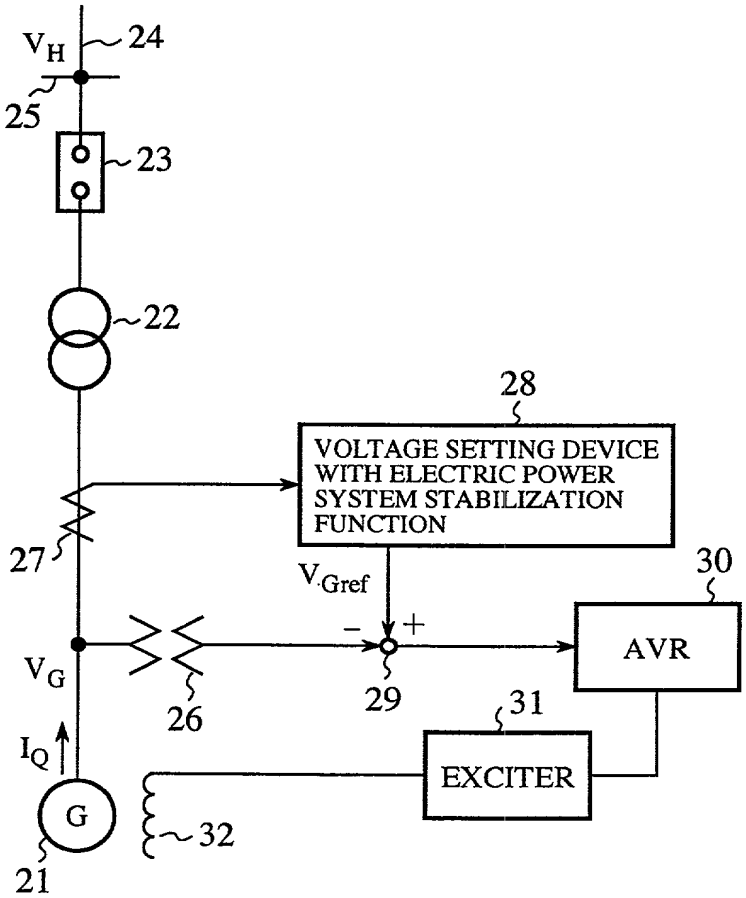

V_H
24
25
23
22
28
VOLTAGE SETTING DEVICE WITH ELECTRIC POWER SYSTEM STABILIZATION FUNCTION
27
V_{Gref}
30
AVR
V_G
26
29
31
I_Q
EXCITER
G
32
21

FIG.5

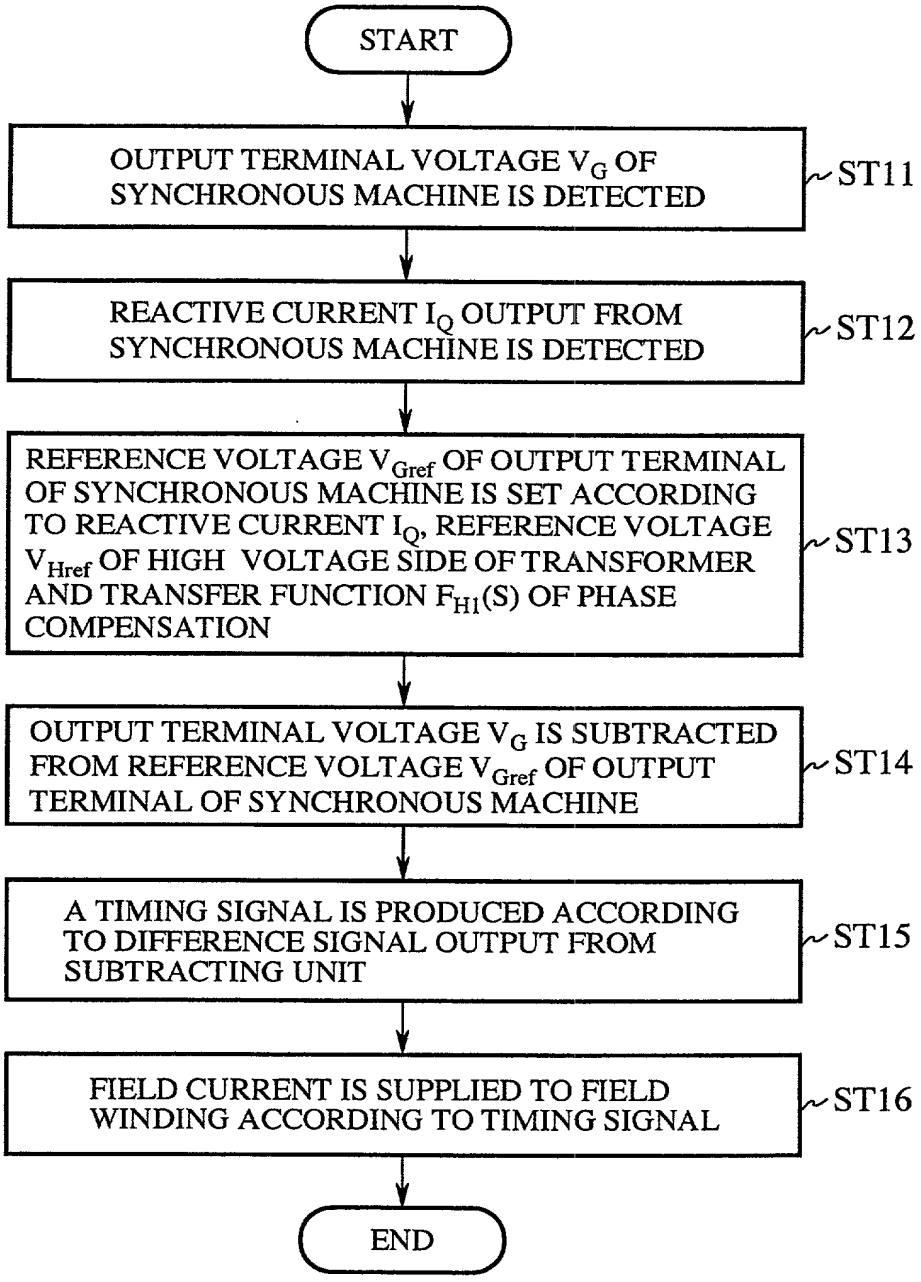

START
OUTPUT TERMINAL VOLTAGE V_G OF SYNCHRONOUS MACHINE IS DETECTED
ST11
REACTIVE CURRENT I_Q OUTPUT FROM SYNCHRONOUS MACHINE IS DETECTED
ST12
REFERENCE VOLTAGE V_{Gref} OF OUTPUT TERMINAL OF SYNCHRONOUS MACHINE IS SET ACCORDING TO REACTIVE CURRENT I_Q, REFERENCE VOLTAGE V_{Href} OF HIGH VOLTAGE SIDE OF TRANSFORMER AND TRANSFER FUNCTION $F_{HI}(S)$ OF PHASE COMPENSATION
ST13
OUTPUT TERMINAL VOLTAGE V_G IS SUBTRACTED FROM REFERENCE VOLTAGE V_{Gref} OF OUTPUT TERMINAL OF SYNCHRONOUS MACHINE
ST14
A TIMING SIGNAL IS PRODUCED ACCORDING TO DIFFERENCE SIGNAL OUTPUT FROM SUBTRACTING UNIT
ST15
FIELD CURRENT IS SUPPLIED TO FIELD WINDING ACCORDING TO TIMING SIGNAL
ST16
END

FIG.6

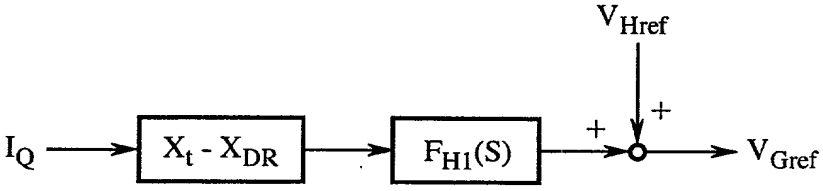

V_{Href}
+
+
I_Q
$X_t - X_{DR}$
$F_{H1}(S)$
V_{Gref}

FIG.7

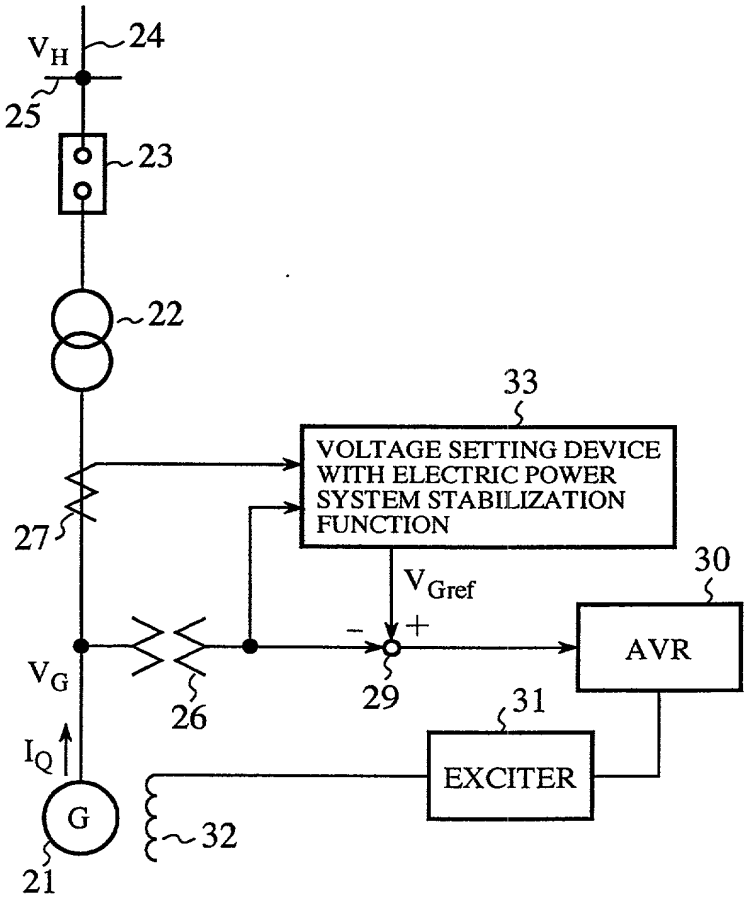

V_H
24
25
23
22
33
VOLTAGE SETTING DEVICE WITH ELECTRIC POWER SYSTEM STABILIZATION FUNCTION
27
V_{Gref}
30
AVR
V_G
26
29
31
I_Q
EXCITER
G
32
21

FIG.8

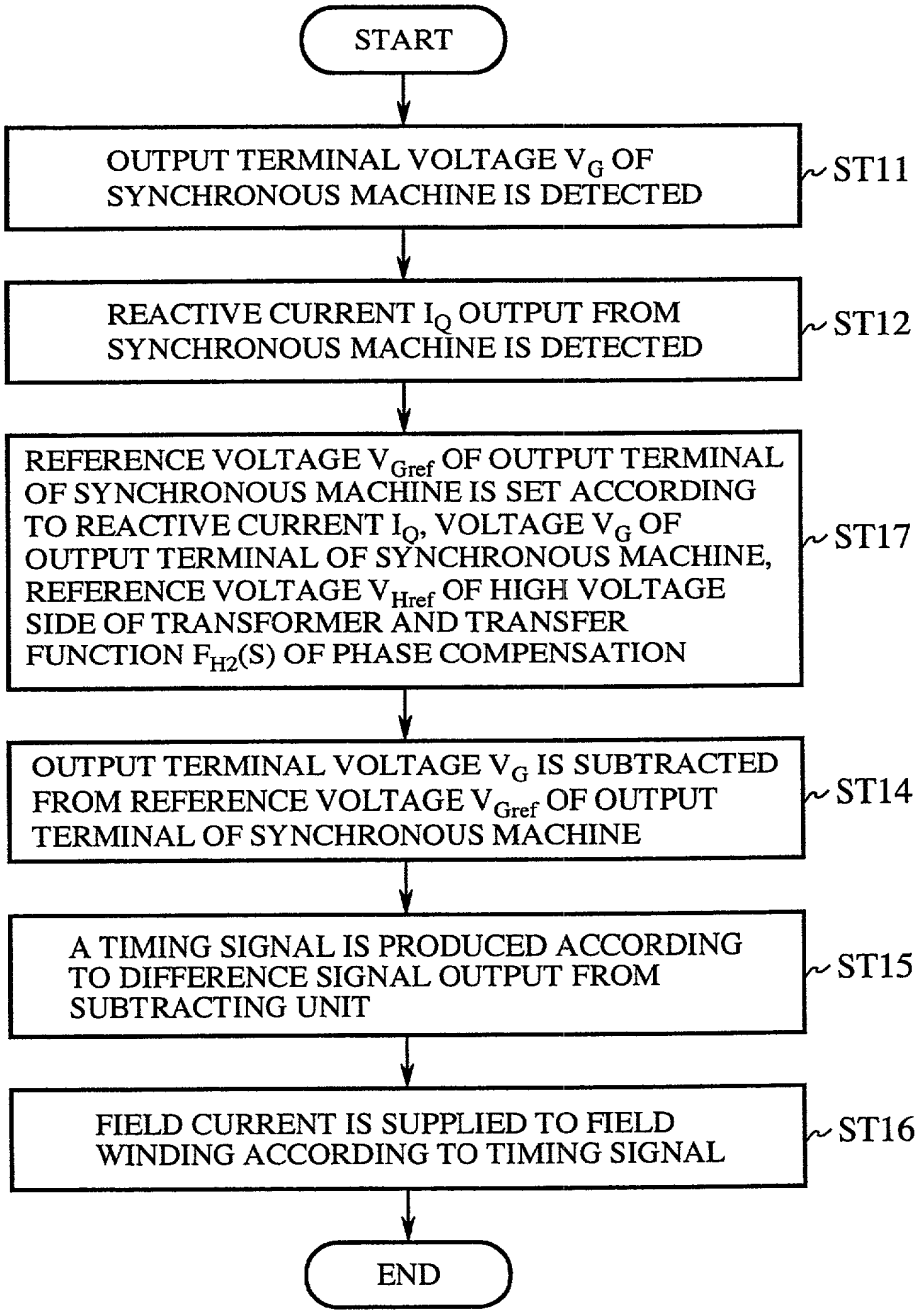
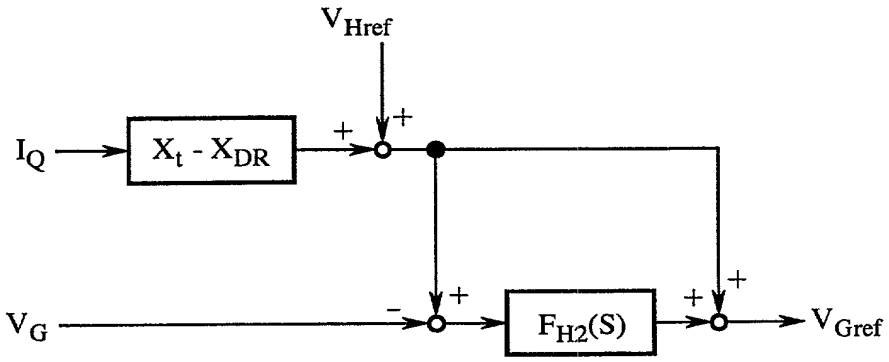

START
OUTPUT TERMINAL VOLTAGE V_G OF SYNCHRONOUS MACHINE IS DETECTED
ST11
REACTIVE CURRENT I_Q OUTPUT FROM SYNCHRONOUS MACHINE IS DETECTED
ST12
REFERENCE VOLTAGE V_{Gref} OF OUTPUT TERMINAL OF SYNCHRONOUS MACHINE IS SET ACCORDING TO REACTIVE CURRENT I_Q, VOLTAGE V_G OF OUTPUT TERMINAL OF SYNCHRONOUS MACHINE, REFERENCE VOLTAGE V_{Href} OF HIGH VOLTAGE SIDE OF TRANSFORMER AND TRANSFER FUNCTION $F_{H2}(S)$ OF PHASE COMPENSATION
ST17
OUTPUT TERMINAL VOLTAGE V_G IS SUBTRACTED FROM REFERENCE VOLTAGE V_{Gref} OF OUTPUT TERMINAL OF SYNCHRONOUS MACHINE
ST14
A TIMING SIGNAL IS PRODUCED ACCORDING TO DIFFERENCE SIGNAL OUTPUT FROM SUBTRACTING UNIT
ST15
FIELD CURRENT IS SUPPLIED TO FIELD WINDING ACCORDING TO TIMING SIGNAL
ST16
END

FIG.9



PATENT

Attorney Docket No. _____

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

This declaration is of the following type:

☐ original ☐ design ☐ supplemental
☒ national stage of PCT
☐ divisional ☐ continuation ☐ continuation-in-part

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first, and sole inventor *(if only one name is listed below)* or an original, first, and joint inventor *(if plural names are listed below)* of the subject matter which is claimed and for which a patent is sought on the invention entitled:

"EXCITATION CONTROL DEVICE AND EXCITATION CONTROL METHOD"

the specification of which:

☐ is attached hereto.
☐ was filed on _____ as Application No. _____
and was amended on _____ *(if applicable)*.
☒ was filed on June 19, 2000 as PCT International Application No. PCT/JP00/03994 and was amended pursuant to PCT Article 19 on _____ *(if any)*.

I state that I have reviewed and understand the contents of the specification identified above, including the claim(s), as amended by any amendment referred to above.

I acknowledge the duty to disclose information that is material to the examination of the application identified above in accordance with 37 CFR §1.56.

I claim foreign priority benefits pursuant to 35 USC §119(a) or §119(d) of any foreign application(s) for patent or inventor's certificate or of any PCT international patent application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent, utility model, design registration, or inventor's certificate or any PCT international patent application(s) designating at least one country other than the United States of America filed by me on the same subject matter and having a filing date before that of the application(s) from which the benefit of priority is claimed.

PRIOR FOREIGN PATENT, UTILITY MODEL, AND DESIGN REGISTRATION APPLICATIONS						
COUNTRY	PRIOR FOREIGN APPLICATION	DATE OF FILING (day,month,year)	PRIORITY CLAIMED UNDER 35 USC §119(a) or §119(d)			
				YES		NO
				YES		NO
				YES		NO

I claim the benefit pursuant to 35 USC §119(e) of the following United States provisional patent application(s):

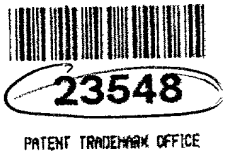
PRIOR U.S. PROVISIONAL PATENT APPLICATIONS, BENEFIT CLAIMED UNDER 35 USC §119(e)	
APPLICATION NO.	DATE OF FILING (day,month,year)

I claim the benefit pursuant to 35 USC §120 of any United States patent application(s) or PCT international patent application(s) designating the United States of America listed below and, insofar as the subject matter of each of the claims of this patent application is not disclosed in the prior patent application(s) in the manner provided by the first paragraph of 35 USC §112, I acknowledge the duty to disclose material information as defined in 37 CFR §1.56 effective between the filing date of the prior patent application(s) and the national or PCT international filing date of this patent application.

PRIOR U.S. PATENT APPLICATIONS OR PCT INTERNATIONAL PATENT APPLICATIONS DESIGNATING THE U.S., BENEFIT CLAIMED UNDER 35 USC §120					
U.S. PATENT APPLICATIONS			Status *(check one)*		
APPLICATION NO.	U.S. FILING DATE		PATENTED	PENDING	ABANDONED
1.					
2.					
3.					
PCT APPLICATIONS DESIGNATING THE U.S.			Status *(check one)*		
PCT APPLICATION NO.	PCT FILING DATE (day,month,year)	U.S. APPLICATION NOS. ASSIGNED (if any)	PATENTED	PENDING	ABANDONED
4.					
5.					
6.					

DETAILS OF FOREIGN APPLICATIONS FROM WHICH PRIORITY CLAIMED UNDER 35 USC §119 FOR ABOVE LISTED U.S./PCT APPLICATIONS				
ABOVE APPLN. NO.	COUNTRY	APPLICATION NO.	DATE OF FILING (day,month,year)	DATE OF ISSUE (day,month,year)
1.				
2.				
3.				
4.				
5.				
6.				

As a named inventor, I appoint the following registered practitioner(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: Customer Number 23548.



I further direct that correspondence concerning this application be directed to Customer Number 23548.

I declare that all statements made herein of my own knowledge are true, that all statements made on information and belief are believed to be true, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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